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Diversity of plant communities and leaf heavy metal content at Luiswishi copper/cobalt mineralization, Upper Katanga, Dem. Rep. Congo

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A study was made of plant communities of the Luiswishi copper/cobalt mineralized outcrop in Katanga Province, Dem. Rep. Congo. The site has been visited in 1926 by Walter Robyns, but was never studied in detail despite its location near Lubumbashi and its differences from the famous site of the "Mine de l'Étoile". Some seven different plant communities were identified, all controlled by the nature of the substratum and its chemical composition. The site is important in that it includes some plants unknown from other mineralized sites in Katanga. The site even contains two endemic plants, each only known from one other metalliferous site. This study completes the former synthesis by Malaisse in 1995 and presents a new phytogeochemical transect across a Katangian copper/cobalt anomaly.
Keywords. Phytogeochemistry, copper, cobalt, plant communities, Luiswishi mine, Katanga, Congo.

Diversité des communautés végétales et teneur foliaire en métaux lourds au gisement cupri-cobaltifère de Luiswishi, Haut Katanga, Rép. Dém. Congo. Une étude des communautés végétales a été effectuée au gisement de cuivre/cobalt de Luiswishi dans la région administrative du Katanga en République démocratique du Congo. Ce site fut visité par Walter Robyns dès 1926, mais ne fut jamais l'objet d'une étude détaillée malgré la proximité de la ville de Lubumbashi et ses différences avec le site célèbre de la Mine de l'Étoile. Quelque sept communautés végétales furent identifiées, toutes sous la dépendance du substrat et de sa composition chimique. Le site est remarquable par la présence de plusieurs plantes non observées sur les autres sites minéralisés du Katanga et de deux espèces endémiques, chacune connue d'un seul autre gisement métallifère. Cette étude complète la synthèse précédente de Malaisse et fournit un nouveau transect phytogéochimique d'une anomalie cupro-cobaltifère au Katanga. .
Mots-clés. Phytogéochimie, cuivre, cobalt, communauté végétale, Mine de Luiswishi, Katanga, Congo.

1. INTRODUCTION

The southeast of Katanga Province, Dem. Rep. Congo, is famous for its copper/cobalt deposits (Brooks *et al.*, 1985) that stretch in a broad zone from Kolwezi in the west to Lubumbashi in the east (**Figure 1**). This mineralized zone is known as the Katangian Copper Bow (François, 1973). Although known principally for its copper and cobalt, the region also contains cadmium, chromium, lead, silver, zinc, uranium and other radioactive minerals (Malaisse *et al.*, 1994).

The Luiswishi ore (**Photos 1** and **2**) was already known from precolonial times, and in 1926, Walter Robyns (1932) paid a visit to the site. Surprisingly, it was never studied in detail (Duvigneaud, Denayer-De Smet, 1963) in spite of its vicinity to the town of Lubumbashi although several expeditions collected some plants, namely Malaisse in 1980–1983, Malaisse and Robbrecht in 1982, Malaisse and Goetghebeur in 1985 and the Tropical Metallophyte Expedition in 1990 (Brooks *et al.* 1992).

Recent political changes occurred in Democratic Republic of Congo have induced important modifications inside ore exploitation policy. Those ones were translated into a new concessions distribution of few deposits, now attributed to several interest groups. If some multinational groups or companies were obliged by financial backers to realize biodiversity studies, and previous environmental approaches allowing to estimate the natural destruction before work (as case

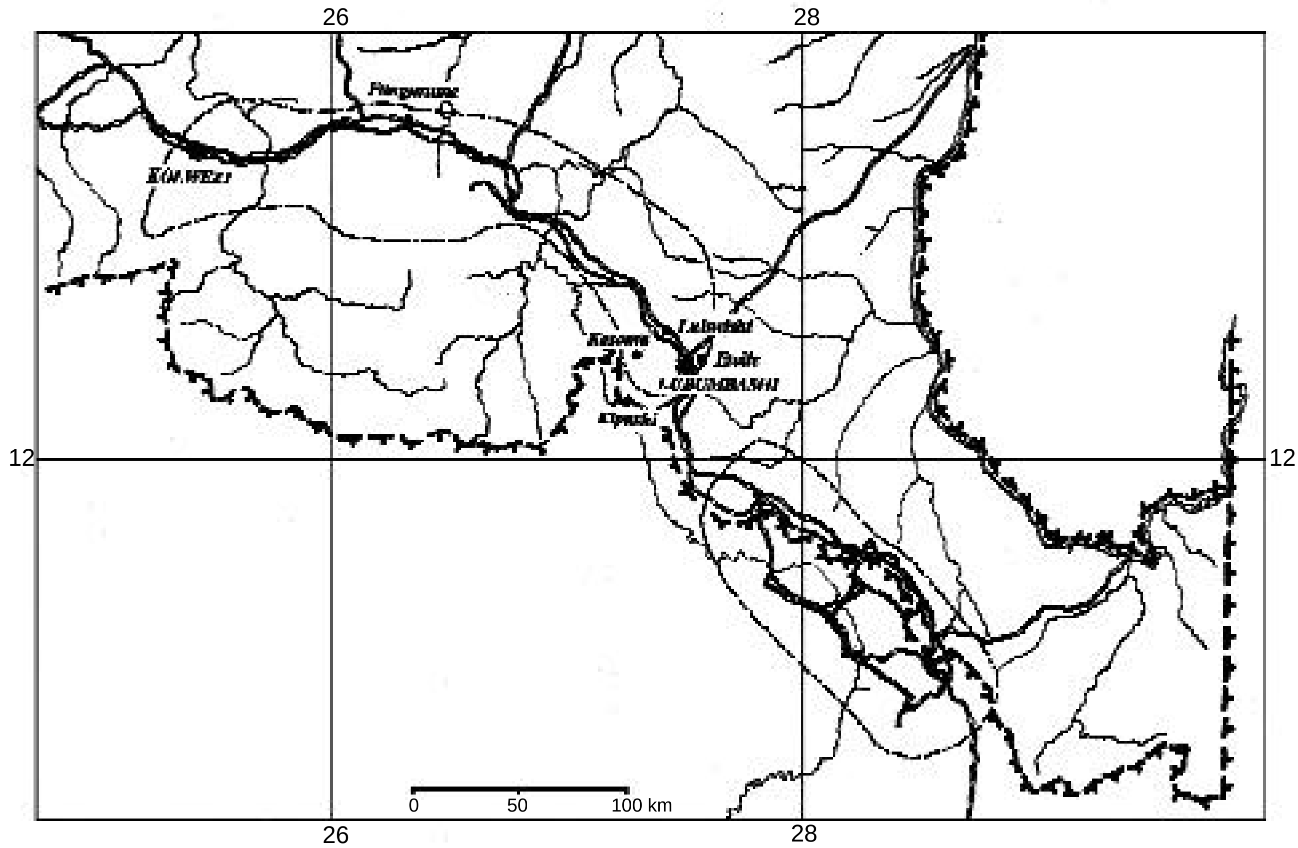

Figure 1. Localization of some copper/cobalt mineralization (black spot) — *Localisation de quelques minéralisations cupro-cobaltifères (point noir).*

Katangian Copper Bow — *Arc cuprifère katangais*

Zambian Copperbelt — *Copperbelt zambienne*

of Tenke-Fungurume mining), the exploitation of others layers was granted to smaller unscrupulous groups. Those smaller groups have worked without worrying about geobotanical preliminar studies and ecological involvement. That is especially the case of Luiswishi and Tilwezembe mines. Consequently, the setting up and publication of any phytogeochemical information, incomplete as it is, constitutes a high importance documentation origin.

Our approach is oriented in this way and aimed to be familiar with the flora, to define some specialist plants, or even to discover metal accumulator plants that should be used to verdurisation works of sterile places. A set of knowledge is already purchased (Leteinturier *et al.*, 1999), but requires every time to be completed by careful observation of each hill because the existence of local endemism at hillock level.

The results of our study carried out in November 1995 are reported below.

2. SITE DETAILS AND CLIMATE

The Luiswishi area is located at 26° 33’45” E, 11° 03’ 25” S, some 25 km NNW of Lubumbashi (**Figure 1**). The site altitude is about 1320 m. Though well within the tropics, the climate is tempered by the elevation. The year is divided into two main seasons, a wet one and a dry one. The wet season lasts from November to early April. During this period rainfalls occurs for a mean number of 114 days. In January, the rainfall is around 250 mm and the mean monthly maximum and minimum temperatures are 26°C and 16°C respectively. The dry season occurs from May to October. In July, there is no rainfall and the mean monthly extreme temperatures are 26°C and 6°C respectively. During the second part of the dry season (September–October), dry warm conditions prevail with extreme temperatures of 32°C and 14°C during October.

Photo 1. View of Luiswishi outcrops from the east — *Vue du gisement de Luiswishi à partir de l'est.*

Photo 2. View of Luiswishi outcrop from the south-west — *Vue du gisement de Luiswishi à partir du sud-ouest.*

3. MATERIALS AND METHODS

Records of vegetation structure and composition were made at two levels. Firstly, a structural – physiognomical survey was performed, based on the classification presented at the Yangambi Conference (Anon., C.S.A./C.C.T.A., 1956). Then, using the Zürich–Montpellier phytosociological method (Werger, 1977), all plant species were listed and given a double coefficient of abundance-dominance and sociability after exploration of surfaces greater than the minimum area assessed. In each plot, dominants and other associated plants were identified.

For chemical analysis, the plant material (leaves) was disintegrated in a mill and the resultant powder dried at 65°C in a drying oven. The samples were then placed in 50 ml borosilicate squat beakers and ashed at 500°C until oxidation was complete (usually after about 3–4 hours). The ash was dissolved in 2M hydrochloric acid with gentle warming and with a final 1/50 ash/acid ratio. The solutions were analysed for copper, cobalt, zinc and cadmium by atomic absorption spectrophotometry using a hydrogen continuum lamp for automatic background correction. All concentration data were expressed on a dry mass basis.

4. RESULTS AND DISCUSSION

4.1. Flora

A list of about 73 plants recorded from mineralized outcrops at Luiswishi is given in **table 1**. The presence of two species will be emphasized. First, *Bulbostylis fusiformis* is presently endemic to the Luiswishi (Goetghebeur, Coudijzer, 1985) and Kasonta (Brooks *et al.*, 1982) outcrops. Secondly, our study reveals the occurrence of *Faroa chalcophila* which was until now only reported from the neighbouring mine of Étoile (Taylor, 1971; Malaisse, Grégoire, 1978; Malaisse *et al.*, 1978), a copper site located at some 16 kilometers of Luiswishi mine. Moreover, 5 species are observed for the first time on heavy metal soils, namely: *Aristolochia heppii*, *Pimpinella acutidentata*, *Trachyandra* sp., *Annona stenophylla* subsp. *nana* and *Gnidia hockii* (**Photo 3**). The last two species have been reported from the high plateau steppish savannas developed on deep Kalahari sands, also on dambo for the first one, but were not observed elsewhere on copper outcrops. Finally, the occurrence on the same hill of two varieties of *Aeollanthus subacaulis* is of interest. Various intermediates between var. *linearis* and var. *ericoides* occur near the mine of Luiswishi (Ryding, 1986), nevertheless typical var. *ericoides*, plants with usually only one stem growing stouter and from a comparatively small tuber (**Photo 4**), are restricted to a well-defined particular site.

4.2. Vegetation

Seven different plant communities (from 1 to 7), including their main characterizing species, are described in the text below (**Figure 2**). These are in general typical of other mineralized sites in Katanga.

The Luiswishi mine was formerly surrounded by woodlands of the wet miombo type. According to the localization of this outcrop in the vicinity of Lubumbashi and to the dynamic population growth of the number of town citizens, the area has been mostly transformed to arable land while the last woodland plots were subjected to firewood production (Malaisse, Binzangi, 1985), so that only a restricted shrub savanna belt (unit 1) has survived. It is dominated by species belonging to the genera *Parinari*, *Baphia* and *Anisophyllea*. **Table 1** lists some of the prominent remaining woody plants.

The Luiswishi mine site appears today as a mosaic of untouched original vegetation and extended low mineralized pitheads covered with a sparse open steppish savanna. On the bottom of these banks, mineralized running water has induced a polluted dambo (unit 2), already recognized elsewhere by Duvigneaud (1958). The vegetal coverage includes both copper resistant plants (*Smilax anceps* and *Pleiotaxis pulcherrima*) from the woodland herbaceous layer and local cuprophilous plants such as *Becium centrali-africanum* and *Triumfetta digitata*.

On the low mineralized earth moved slopes, *Rendlia altera* has built heavy carpets (unit 3).

A further vegetation (unit 4) takes over on the horizontal ground plains. Those surfaces result from reworked rocky ore material (fillings). The presence of two geophytes with perennial corms, *Eriosema shirense* and *Eriospermum abyssinicum*, underlines the skeletal substratum. Locally, two *Bulbostylis* spp. are observed (unit 4b): for example, *B. pseudoperennis*, widely distributed on Katangian copper outcrops.

Natural cuprophilous steppe also occurs (unit 5) with over twenty different species. This relative species richness contrasts with the four former units. Beside the well-known copper ore plants such as *Pandiaka carsonii* var. *linearifolia*, *Adenodolichos rhomboideus*, *Thesium* cf. *pawlowskianum*, *Triumfetta digitata*, *T. welwitschii*, *Gladiolus tshombeanus*, *Cyanotis longifolia*, *Crotalaria cornetii*, some other unusual plants are present such as *Gnidia hockii* and *Annona stenophylla*. A few ore prospection ditches about 60 cm wide × 1,5 m depth persist (unit 5b). In the heart of these places, humic dark brown soil deposits are suitable for the development of hardy plants, namely: *Chlorophytum sphacelatum* and *Haumaniastrum katangense* restricted at Luiswishi mine to this particular habitat.

Table 1. Species recorded on mineralized outcrops at Luiswishi — *Espèces végétales relevées sur les gisements minéralisés de Luiswishi*.

Family	Herbarium number	Dominant species
1. SHRUB SAVANNABELT DERIVED FROM MIOMBO WOODLAND (Woody species)		
Anisophylleaceae	M 12893	*Anisophyllea boehmii* Engl.
Chrysobalanaceae	M 13301	*Parinari curatellifolia* Planch. ex Benth.
Fabaceae	M 5586	*Baphia bequaertii* De Wild.
Hymenocardiaceae	M 6760	*Hymenocardia acida* Tul.
Loganiaceae	M 6572	*Strychnos cocculoides* Baker
Melastomataceae	M 12931	*Memecylon flavorvirens* Baker
Meliaceae	M 10008	*Ekebergia benguelensis* Welw. ex C.DC.
Mimosaceae	M 6483	*Albizia andianthifolia* (Schum.) W.F. Wight
2a. STEPPISH SAVANNABELT POLLUTED DAMBO		
Aristolochiaceae	M 14235	*Aristolochia heppii* Merxm.
Asparagaceae	B 565	*Asparagus abyssinicus* Hochst. ex A. Rich.
Asteraceae	M 14234	*Pleiotaxis pulcherrima* Steetz
Euphorbiaceae	M 14238	*Phyllanthus reticulatus* Poir.
Lamiaceae	M 14237	*Becium centrali-africanum* (Fries) Sebald
Menispermaceae	M 9265	*Stephania abyssinica* (Dill. & A. Rich.) Walp.
Rubiaceae	M 14239	*Fadogiella* cf. *stigmatoloba* (K. Schum.) Robyns
Rubiaceae	M 14227	*Lelya prostrata* (Good) Lewis var. *prostrata*
Smilacaceae	M 13 392	*Smilax anceps* Willd.
Tiliaceae	M 12173	*Triumfetta digitata* (Oliv.) Sprague & Hutch.
2b. STEPPISH SAVANNABELT (GENTLY SLOPING)		
Apiaceae	M 12830	*Pimpinella acutidentata* Norman
Caesalpiniaceae	M 7570	*Cassia mimosoides* L.
Commelinaceae	WR 1705	*Commelina bequaerti* De Wild.
Fabaceae	M 14249	*Aeschynomene pygmaea* Baker var. *hebecarpa* J. Léon.
Fabaceae	TROPMETEX 2	*Pseudarthria hookeri* Wight & Arn.
Hypolepidiaceae	M 5395	*Pteridium aquilinum* (L.) Kuhn. subsp. *centrali-africanum* Hieron.
Lamiaceae	M 14228	*Becium obovatum* (E. Mey. ex Benth.) N. E. Br. subsp. *obovatum* var. *obovatum*
Liliaceae	M 14232	*Trachyandra* sp.
Liliaceae	M 14247	*Chlorophytum* cf. *colubrinum* (Welw. ex Baker) Engl.
Orchidaceae	M 11646	*Habenaria* cf. *perpulchra* Kraenzlin
Oxalidaceae	Q 5234	*Oxalis obliquifolia* Steud. ex A. Rich.
Vitaceae	M 11420	*Cyphostemma sessilifolium* (Dewit) Descoings
3. CUPROPHILOUS STEPPISH SAVANNAON SLOPE ESTABLISHED ON EARTH MOVED		
Fabaceae	M 14236	*Eriosema shirense* Bak.
Iridaceae	M 14233	*Gladiolus tshombeanus* P.A. Duvigneaud & Van Bockstal
Poaceae	M 9287	*Rendlia altera* (Rendle) Chiov.
4a. CUPROPHILOUS STEPPISH SAVANNAON PLATEAU		
Cyperaceae	M & G 473	*Bulbostylis fusiformis* Goetghebeur
Eriospermaceae	M 14254	*Eriospermum abyssinicum* Bak.
Fabaceae	M 14236	*Eriosema shirense* Bak.
Gentianaceae	M 14250	*Faroa chalcophila* P. Taylor
Malvaceae	M 12985	*Hibiscus rhodanthus* Gürke
Poaceae	M 9287	*Rendlia altera* (Rendle) Chiov.

Table 1. Continued.

Family	Herbarium number	Dominant species
4b. LOCAL CUPROPHILOUS STEPPISH SAVANNA		
Cyperaceae	M & G 473	*Bulbostylis fusiformis* Goetghebeur
Eriospermaceae	M 14254	*Eriospermum abyssinicum* Bak.
Fabaceae	M 14236	*Eriosema shirense* Bak.
Gentianaceae	M 14250	*Faroa chalcophila* P. Taylor
Malvaceae	M 12985	*Hibiscus rhodanthus* Gürke
Poaceae	M 9287	*Rendlia altera* (Rendle) Chiov.
5a. CUPROPHILOUS STEPPE		
Acanthaceae	M 14240	*Thunbergia* aff. *oblongifolia* Oliv.
Acanthaceae	M 14241	*Justicia* cf. *lolioides* S. Moore
Amaranthaceae	M 14243	*Pandiaka carsonii* (Baker) C.B. Clarke var. *linearifolia* Hauman
Annonaceae	M 14226	*Annona stenophylla* Engl. & Diels subsp. *nana* (Exell) N. Robson
Aristolochiaceae	M 14221	*Aristolochia hockii* De Wild. subsp. *hockii*
Asteraceae	M 14229	*Senecio* cf. *coronatus* (Thunb.) Harv.
Asteraceae	M 10597	*Vernonia suprafastigiata* Klatt
Caesalpiniaceae	M 9836	*Cryptosepalum maraviense* Oliv.
Commelinaceae	M 10488	*Cyanotis longifolia* Benth.
Cyperaceae	M 14230	*Bulbostylis macra* (Ridl.) C.B. Clarke
Cyperaceae	M 12165	*Ascolepis metallorum* P.A. Duvigneaud & G. Léonard
Cyperaceae	M 14245	*Ascolepis* cf. *protea* Welw. var. *bellidiflora* (Welw.)Lye
Cyperaceae	S 1257	*Cyperus kibweanus* Duvign.
Eriospermaceae	M 14254	*Eriospermum abyssinicum* Baker
Euphorbiaceae	M 13575	*Euphorbia cyparissioides* Pax
Fabaceae	M 10233	*Adenodolichos rhomboideus* (O. Hoffm.) Harms
Fabaceae	M 7931	*Crotalaria cornetii* Taub. & Dewèvre
Iridaceae	M 14233	*Gladiolus tshombeanus* P.A. Duvigneaud & Van Bockstal
Lamiaceae	M 14237	*Becium centrali-africanum* (Fries) Sebald
Malvaceae	M 12985	*Hibiscus rhodanthus* Gürke
Polygalaceae	M 11027	*Polygala katangensis* Exell
Rubiaceae	M 14242	*Fadogia cienkowskii* Schweinf.
Rubiaceae	M 12826	*Manostachya staelioides* (K. Schum.) Bremek.
Santalaceae	M 14244	*Thesium* cf. *pawlowskianum* Lawalrée
Santalaceae	M 6012	*Thesium quarrei* Robyns & Lawalrée
Thymeleaceae	M 14248	*Gnidia hockii* De Wild.
Tiliaceae	M 12173	*Triumfetta digitata* (Oliv.) Sprague & Hutch.
Tiliaceae	M 7990	*Triumfetta welwitschii* Mast.
5b. LOCALCUPROPHILOUS STEPPE (IN DITCH)		
Cyperaceae	M & R 2111	*Bulbostylis fusiformis* Goetghebeur
Lamiaceae	M 10543	*Haumaniastrum katangense* (S. Moore) P.A. Duvigneaud & Plancke
Lamiaceae	M 13028	*Aeollanthus subacaulis* (Baker) Briq. var. *linearis* (Burk.) Ryding
Liliaceae	M 12904	*Chlorophytum sphacelatum* Bak.
Scrophulariaceae	Kis & Muz 71	*Alectra sessiliflora* (Valh) O. Ktze var. *senegalensis* (Benth.) Hepper

Table 1. Continued.

Family	Herbarium number	Dominant species
6a. CUPROPHILOUS STEPPE ON SLOPE		
Caesalpiniaceae	M & G 1068	*Cryptosepalum maraviense* Oliv.
Cyperaceae	S 1257	*Cyperus kibweanus* P.A. Duvigneaud
Fabaceae	M & R 2124	*Crotalaria cornetii* Taub. & Dewèvre
Iridaceae	M 13027	*Gladiolus tshombeanus* P.A. Duvigneaud & Van Bockstal
Lamiaceae	M 14228	*Becium obovatum* (E. Mey. ex Benth.) N. E. Br. subsp. *obovatum* var. *obovatum*
Lamiaceae	M & R 2101	*Haumaniastrum homblei* (De Wild.) P.A. Duvigneaud & Denayer
Poaceae	M & R 2123	*Monocymbium ceresiiforme* (Nees) Stapf
Rubiaceae	M 12826	*Manostachya staelioides* (K. Schum.) Bremek.
6b. CUPROPHILOUS STEPPE OF VELLOZIACEAE (ON SLOPE)		
Asteraceae	TROPMETEX 19	*Vernonia stenocephala* Oliv.
Lamiaceae	M 11677	*Aeollanthus subacaulis* (Bak.) Hua & Briq. var. *ericoides* (De Wild.) Ryding
Olacaceae	M 9315	*Olax obtusifolia* De Wild.
Velloziaceae	M 12832	*Xerophyta equisetoides* Baker var. *equisetoides*
7. SHRUB SAVANNA		
Caesalpiniaceae	M 7113	*Julbernardia paniculata* (Benth.) Troupin
Chrysobalanaceae	M 5136	*Parinari curatellifolia* Planch. ex Benth.
Euphorbiaceae	M 13359	*Uapaca kirkiana* Müll. Arg.
Fabaceae	M 12160	*Indigofera sutherlandoides* Baker
Meliaceae	M 9360	*Ekebergia benguellensis* Welw.
Polygalaceae	TROPMETEX 11	*Securidaca longepedunculata* Fresen var. *parvifolia* Oliv.
Proteaceae	M 10246	*Protea welwitschii* Engl.

B = Bulaimu; G = Goetghebeur; Kis = Kisimba; M = Malaisse; Muz = Muzinga; Q = Quarré; R = Robbrecht; S = Schaijes; TROPMETEX = Tropical Metallophyte Expedition (Baker, Brooks, Schat and Malaisse); WR = W. Robyns.
The reference collection is deposited at the herbarium of the Jardin botanique national de Belgique (BR) at Meise (Belgium).

A natural site overhangs the cuprophilous steppe. On the lower part, another cuprophilous steppe is located on a gentle slope (unit 6). A distinct set of species belonging to the cuprophilous steppe is noted: *Monocymbium ceresiiforme*, *Cryptosepalum maraviense*, *Haumaniastrum homblei* and *Crotalaria cornetii*. Moreover, *Cyperus kibweanus*, *Manostachia staelioides* and *Gladiolus tshombeanus* are of particular interest. The ecotone to the shrub savanna developed near and on the summit is located on a steep slope and delimited by the typical black short stems of *Xerophyta equisetoides* (unit 6bis). *Olax obtusifolia* occurs and is poorly developed, less than 60 cm high. *Aeollanthus subacaulis* var. *ericoides*, a stable cobalt hyperaccumulator, is restricted to this site. Short cylindrical termite mounts of *Cubitermes* were only observed in this narrow belt.

In the shrub savanna, the most abundant components (unit 7) are *Securidaca longepedunculata* var. *parvifolia* and *Protea welwitschii*. Dwarf stressed miombo trees may be observed such as *Julbernardia paniculata*, *Parinari curatellifolia* and *Uapaca kirkiana*. It should be noted that *Olax obtusifolia* and *Securidaca longepedunculata* have been observed together on medium-rich copper soils at Copper Queen Mine in Zimbabwe (Ernst, 1993).

Photo 3. Aspect of the geofrutex *Gnidia hockii* — *Aspect du geofrutex* Gnidia hockii.

Photo 4. *Aeollanthus subacaulis* var. *ericoides*

4.3. Cobalt, copper, zinc and cadmium uptake by plants

Table 2 presents a collation of cobalt, copper, cadmium and zinc analyses for 39 plant samples collected at Luiswishi. It demonstrates a very wide range of metal concentrations: 0–1429 $\mu g \cdot g^{-1}$ dry weight for cobalt, 7–205 $\mu g \cdot g^{-1}$ for copper, 10–226 $\mu g \cdot g^{-1}$ for zinc and 0.04–4.31 $\mu g \cdot g^{-1}$ for cadmium. A value of >1000 $\mu g \cdot g^{-1}$ dry weight was defined by Brooks (1977) as evidence for "hyperaccumulation" of copper. Baker and Brooks (1989) listed 24 hyperaccumulators of copper and 26 of cobalt, 9 of which were hyperaccumulators of both metals. The present study has revealed two copper-resistant plants: *Bulbostylis cupricola* (Cyperaceae) and *Pimpinella acutidentata* (Apiaceae). In the case of cobalt, the existence of one hyperaccumulator was noted, *Aeollanthus subacaulis* var. *ericoides*, already known for its impressive adaptation on metallic soils (Brooks *et al.*, 1987). High cobalt contents of *Senecio* cf. *coronatus* (*Asteraceae*) should also be noted. For secondary metals like zinc and cadmium, some results are of interest. Regarding zinc, its contents on metalliferous soils in Katanga, with the exception of Kipushi mine, is relatively low; values lower or around 500 $\mu g \cdot g^{-1}$ of dry soil have been reported (Malaisse, Grégoire, 1978). The geometric mean of zinc concentration in leaves of 838 specimens collected on Katangian copper/cobalt deposits is of 85 $\mu g \cdot g^{-1}$. In this material, the zinc content of leaves is strongly correlated with those of Cu and S (Brooks *et al.*, 1987), but the nature of chemical bounds appears fundamentaly different: nickel is mainly bound to simple organic acids (such as citric acid and malic acid) whereas copper is bound to several ligands (Morrison *et al.*, 1981). Although citrate also appears to be the major nickel-binding ligand in extracts from several other hyperaccumulators from New Caledonia (Lee *et al.*, 1977; Kersten *et al.*, 1980) and other tropical areas (Homer, 1991), in European hyperaccumulators (*Alyssum*), the nickel is extracted in association with malate and malonate (Brooks *et al.*,

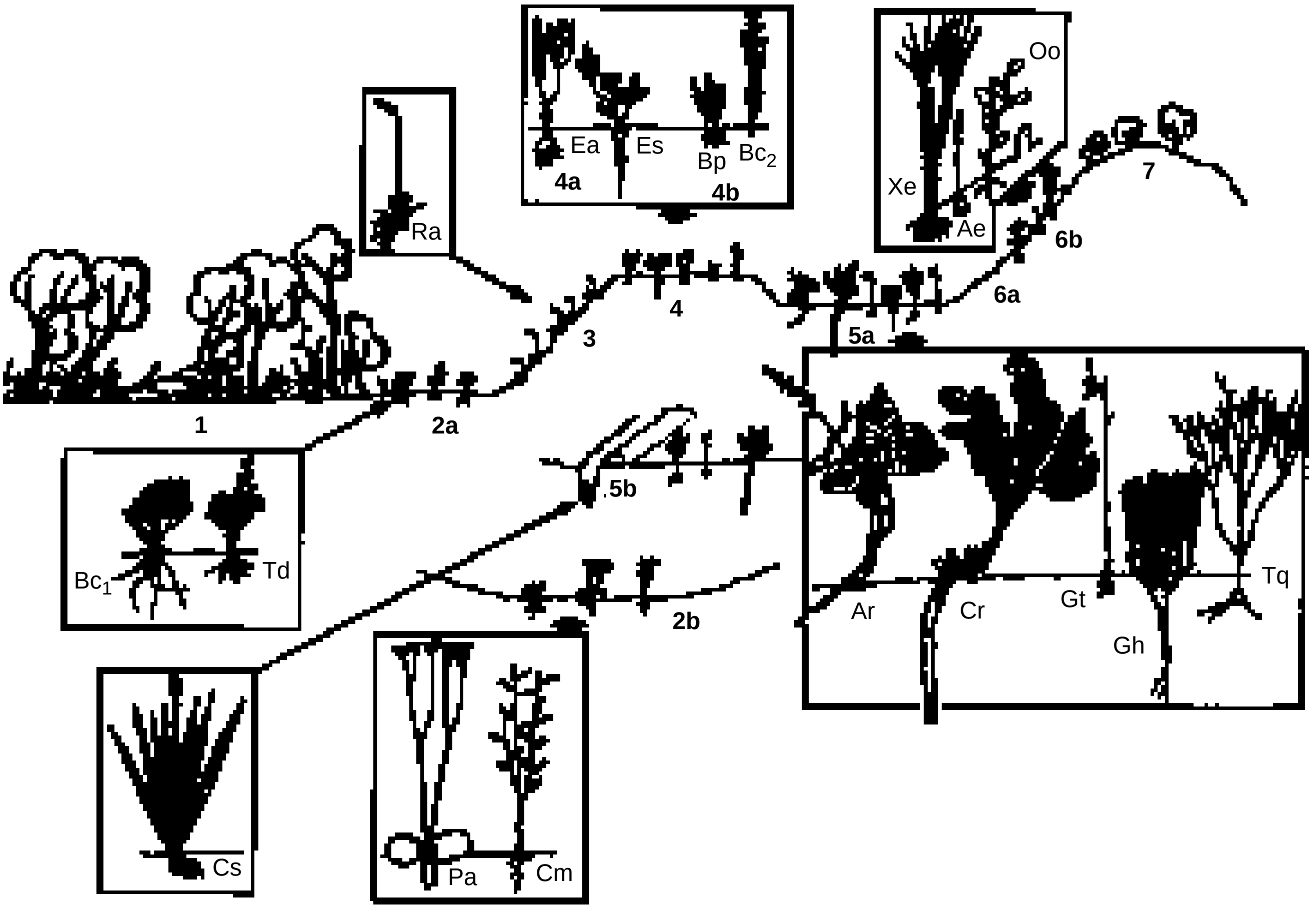

Figure 2. Localization of seven plant communities at Luiswishi mineralized outcrops — *Localisation de sept communautés végétales au gisement minéralisé de Luiswishi* (Ae = *Aeollanthus subacaulis* var. *ericoides*; Ar = *Adenodolichos rhomboideus*; Bc_1 = *Becium centrali-africanum*; Bc_2 = *Bulbostylis cupricola*; Bp = *Bulbostylis pseudoperennis*; Cm = *Cassia mimosoides*; Cr = *Cryptosepalum maraviense*; Cs = *Chlorophytum sphacelatum*; Ea = *Eriospermum abyssinicum*; Es = *Eriosema shirense*; Gh = *Gnidia hockii*; Gt = *Gladiolus tshombeanus*; Oo = *Olax obtusifolia*; Pa = *Pimpinella acutidentata*; Ra = *Rendlia altera*; Td = *Triumfetta digitata*; Tq = *Thesium quarrei*; Xe = *Xerophyta equisetoides* var. *equisetoides*).

1982). Therefore, it must be far more regarding nickel hyperaccumulation than simply resulting from production of additional amounts of ligands such as citrate and malate (Reeves, 1992). The zinc content of leaves of *Euphorbia cyparissioides* (Euphorbiaceae) (226 $\mu g \cdot g^{-1}$) fits well with the highest values reported from the Étoile mine by Malaisse and Grégoire (1978). The variable morphological aspect, leaf anatomy, as well as leaf mineral content of *Pandiaka carsonii* (Amaranthaceae) has already been discussed (Malaisse, 1983). The copper content of the narrow-leaved ecotype is about 10 times less at Luiswishi, in comparison with those reported from Fungurume hill (Malaisse *et al.*, 1979; Brooks *et al.*, 1980), whereas the zinc content is of some importance. This last comment applies also for *Eriospermum abyssinicum*. Regarding cadmium, *Gnidia hockii* is conspicuous by a content seven times greater than the overall mean (0.57 $\mu g \cdot g^{-1}$).

5. CONCLUDING COMMENTS

The work at Luiswishi has added to our knowledge of the flora and the vegetation of the cobalt and copper deposits of Katanga Province. The Luiswishi site survey enlarges the copper-cobalt flora diversity. Because of his high endemism (as an endemic sedge and the endemic annual Gentianaceae), this site provides complementary information about new tolerant or hyperaccumulator plants that could be destroyed by continuous exploitation of the place. Our approach carried out some metallic supporting plants that maybe will disappear in the future. Consequently, scientific surveys as Luiswishi plant diversity are the basis of a new question about plant diversity and biodiversity conservation. Some tropical environments are in full protection because of their green and attractive appearance, nevertheless it is urgent to regard the richness of other less spectacular natural environments.

Table 2. Cobalt, copper, zinc and cadmium contents of plants (µg·g^{-1} dry weight) at Luiswishi — *Teneurs en cobalt, cuivre, zinc et cadmium de plantes (µg·g^{-1} poids sec) à Luiswishi*.

Species	Plant content in			
	Cobalt (µg·g^{-1})	Copper (µg·g^{-1})	Zinc (µg·g^{-1})	Cadmium (µg·g^{-1})
Aeollanthus subacaulis var. *ericoides* – LAMIACEAE	1429	169	~	~
Senecio cf. *coronatus* – ASTERACEAE	718	26	14	0.68
Phyllanthus reticulatus – EUPHORBIACEAE	504	11	15	0.44
Bulbostylis fusiformis – CYPERACEAE	353	49	104	2.80
Commelina bequaertii – COMMELINACEAE	314	40	101	0.61
Hibiscus rhodanthus – MALVACEAE	212	74	33	1.72
Bulbostylis cupricola – CYPERACEAE	156	205	~	~
Lelya prostrata var. prostrata – RUBIACEAE	144	140	53	1.62
Triumfetta digitata – TILIACEAE	107	42	54	1.23
Pandiaka carsonii var. *linearifolia* – AMARANTHACEAE	106	27	119	0.49
Cyperus kibweanus – CYPERACEAE	106	13	~	~
Pimpinella acutidentata – APIACEAE	85	186	~	~
Becium obovatum subsp. *obovatum* – LAMIACEAE	75	31	38	0.42
Euphorbia cyparissioides – EUPHORBIACEAE	64	7	226	0.21
Ascolepis metallorum – CYPERACEAE	64	45	72	0.85
Aeschynomene pygmaea var. *hebecarpa* – FABACEAE	57	72	73	0.57
Aristolochia heppii – ARISTOLOCHIACEAE	54	12	14	0.04
Gnidia hockii – THYMELEACEAE	45	24	71	4.31
Vernonia suprafastigiata – ASTERACEAE	41	38	40	0.41
Chlorophytum sphacelatum – LILIACEAE	38	23	52	0.96
Becium centrali-africanum – LAMIACEAE	34	18	25	0.22
Eriospermum abyssinicum – ERIOSPERMACEAE	32	22	137	0.38
Justicia cf. *lolioides* – ACANTHACEAE	26	48	45	0.19
Fadogia cienkowskii – RUBIACEAE	25	10	17	0.45
Eriosema shirense – FABACEAE	24	20	28	0.68
Thesium quarrei – SANTALACEAE	21	19	34	0.04
Pleotaxis pulcherrima – ASTERACEAE	19	29	10	0.16
Pteridium aquilinum subsp. *centrali-africanum* – HYPOLEPIDIACEAE	17	9	22	0.10
Thunbergia aff. *oblongifolia* – ACANTHACEAE	17	27	22	0.43
Fadogiella cf. *stigmatoloba* – RUBIACEAE	14	25	12	0.22
Ascolepis cf. *protea* var. *bellidiflora* – CYPERACEAE	14	15	45	0.63
Adenodolichos rhomboideus – FABACEAE	11	13	29	0.09
Cryptosepalum maraviense – CAESALPINIACEAE	10	14	29	0.15
Protea welwitschii – PROTEACEAE	6	10	18	0.43
Thesium quarrei – SANTALACEAE	3	10	54	0.85
Annona stenophylla subsp. *nana* – ANNONACEAE	2	9	10	0.23
Aristolochia hockii subsp. *hockii* – ARISTOLOCHIACEAE	1	17	34	0.35
Alectra sessiliflora – SCROPHULARIACEAE	0	10	32	0.20

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